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Research and Development

National Risk Management Research Laboratory
Research Triangle Park, NC 27711

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Project Summary

The Carnol Process for CO_2 Mitigation from Power Plants and the Transportation Sector

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An alternative carbon dioxide (CO_2) mitigation process has been conceived and its feasibility investigated. The Carnol process is directed to reduce CO_2 emission primarily from coal burning power plants and producing methanol as an alternative automotive fuel. By-product carbon produced is either stored or sold as a materials commodity. A process simulation computer model is used to perform materials and energy balances. Preliminary economics of the process is evaluated. Two advanced unit process developments are identified for improving the utilization of this process.

This Project Summary was developed by EPA's National Risk Management Research Laboratory's Air Pollution Prevention and Control Division, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

A CO_2 greenhouse gas mitigation process is introduced and developed. The Carnol process takes CO_2 recovered from the stack gases of a coal-fired power plant and reacts it with hydrogen produced by the thermal decomposition of natural gas (methane) to produce methanol as a liquid alternative transportation fuel. The reduction to near-zero CO_2 emission results from the removal of CO_2 from the coal burning plant and the emission of an equivalent amount of CO_2 when the methanol is burned as fuel. The carbon produced from the methane decomposition step is not used as fuel but is either stored or sold as a materials commodity.

Process Chemistry

The process chemistry depends on two reactions:

Methane Decomposition:

$$CH_4 = C + 2H_2$$

Methanol Synthesis:

$$CO_2 + 3H_2 = CH_3OH + H_2O$$

The overall stoichiometry of the process is:

$$3CH_4 + 2CO_2 = 2CH_3OH + 2H_2O + 3C.$$

The net CO_2 generation for the production and utilization of methanol is zero, since 1 mol is recovered from the power plant and 1 mol is produced when methanol is used as fuel.

Process Design

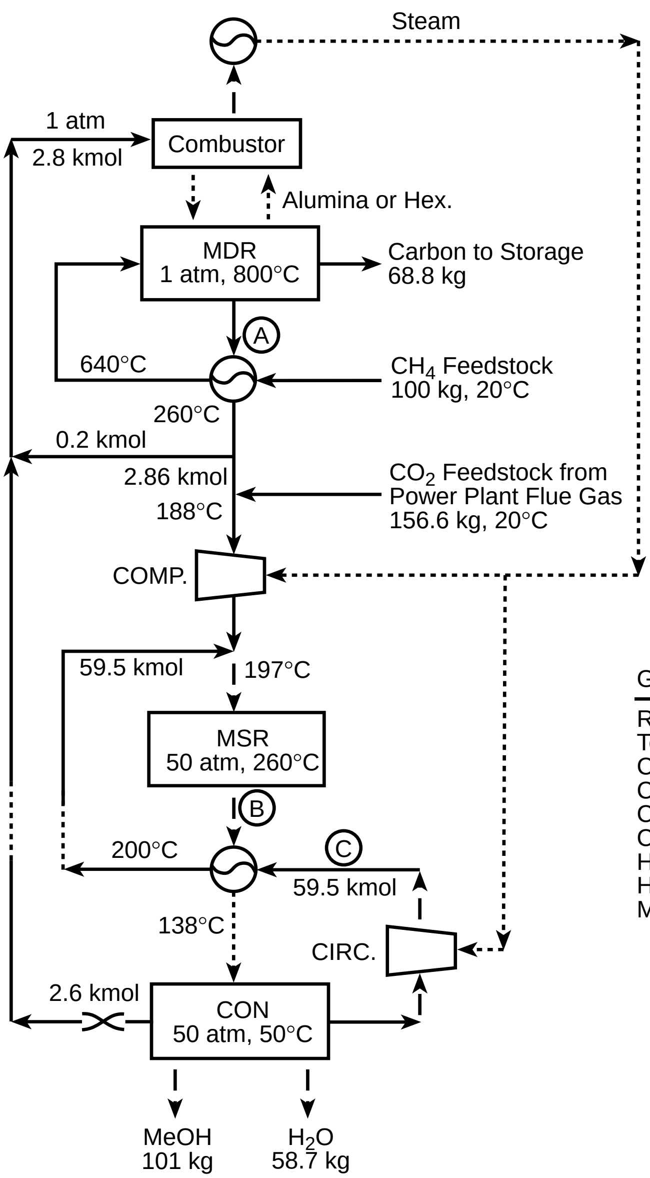
Based on the thermodynamics and kinetics of methane decomposition, the conditions for a Methane Decomposition Reactor (MDR) require operating temperatures of 800°C and above at 1 atm* pressure. A circulating heated alumina fluid-

(*) For readers more familiar with metric units: 1 atm = 101 kPa; 1 bbl = 159 L; 1 ton = 0.9 metric ton; and 1 lb/10^6 Btu = 0.43 kg/GJ.

ized-bed reactor supplies the energy required to decompose the methane. The methanol synthesis reactor (MSR) is a conventional catalytic system operating at 260°C and pressures of 30 to 50 atm. An equilibrium based process simulation model is used to produce mass and energy balances based on the process flow diagram shown in Figure 1. It was found that CO_2 emission reduction of 90% and above can be achieved by the Carnol process compared to that produced by the conventional methane steam reforming process. The thermal efficiency for methanol production is 41% and the co-product carbon conversion efficiency based on methane is 92%.

Preliminary Economics

A preliminary economic evaluation is made feeding CO_2 recovered from a 600 MW(e) coal-fired power plant, together with natural gas to produce 61,100 bbl/day of methanol and 5800 tons/day of carbon. Depending on the cost of natural gas, the cost of CO_2 recovery, the market price of methanol, and the possible market value of carbon, the cost of CO_2 emission reduction can vary from an income of \$103/ton to an expenditure of \$55/ton CO_2 recovered from the power plant. The latter is less than the highest cost estimated for recovery of CO_2 from a coal-fired power plant located near a coast and disposal of the CO_2 in the ocean. The application of CO_2 mitigation technologies, such as the Carnol process, depends to some extent on how seriously the country and the world take the global greenhouse gas warming problem since such an approach would involve massive capital investments and fundamental changes in the country's energy use patterns.



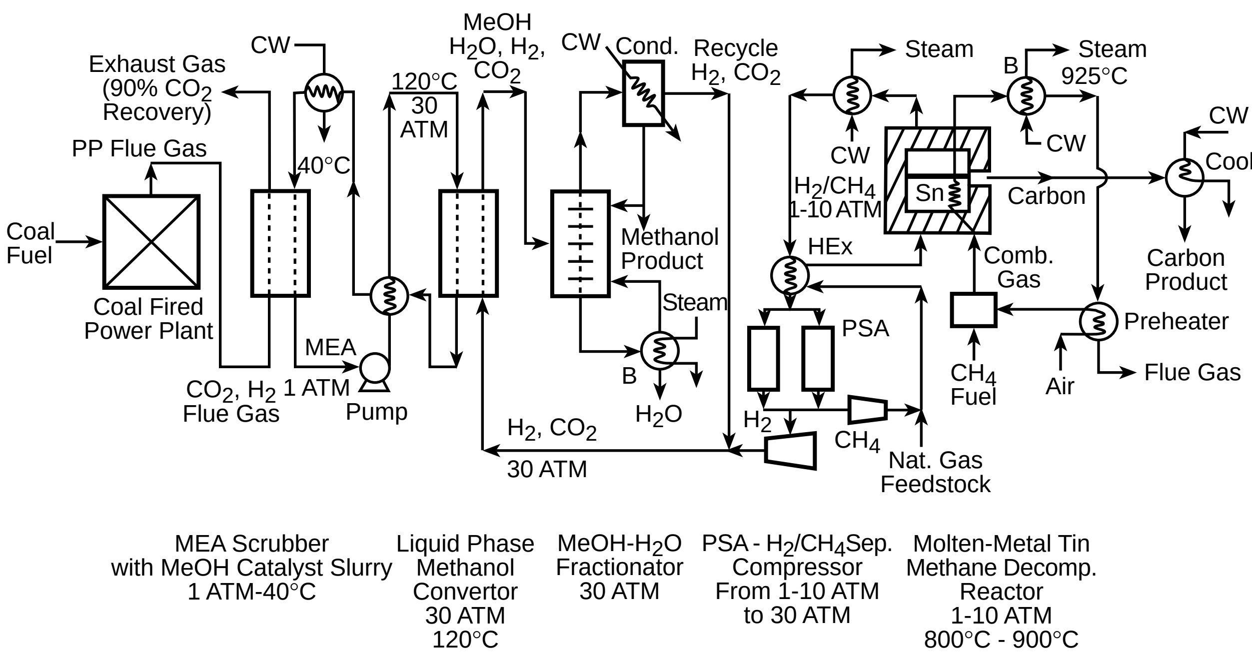
Carbon Efficiency 50.3%
Thermal Efficiency 41.1%
CO_2 Emission 22.7 lb/10^6 Btu
Basis 100 kg CH_4 Feed

Gas Stream	A	B	C
Rate - kmol	12.0	70.4	64.0
Temp - °C	800	260	50
Comp. mol %			
CO		3.35	3.68
CO_2		12.86	14.15
CH_4	4.25	17.34	19.08
H_2O		4.76	0.14
H_2	95.75	56.67	62.34
MeOH		5.02	0.60

Figure 1. CO_2 mitigation technology Carnol-III + process.

Process Improvements

Two important process improvements for lowering the cost of the Carnol process are identified for further research and development: (1) the use of a molten metal bath reactor for thermally decomposing methane and (2) the use of a liquid phase slurry catalyst for synthesizing methanol by the reaction of hydrogen with CO_2 in a monoethanolamine (MEA) solvent. The conceptual process diagram including these developments is shown in Figure 2.



Process Chemistry:

Feedstock ↓ → Product

$$3/2\ CH_4 = 3/2\ C + 3H_2 \quad \leftarrow \text{Nat. Gas, Decomp.}$$

$$3\ H_2 + CO_2 = CH_3OH + H_2O \quad \leftarrow \text{MeOH Synthesis}$$

↑ Flue Gas ↓ Product

Figure 2. Carnol-VI process for CO_2 mitigation technology--combining CO_2 recovery from power plants with liquid metal methane decomposition and liquid-phase methanol synthesis.

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The complete report, entitled "The Carnol Process for CO_2 Mitigation from Power Plants and the Transportation Sector," (Order No. PB96-145 065; Cost: $19.50, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

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